

AN ABSTRACT OF THE THESIS OF

Brenda M. Krivak for the degree of Master of Arts in Interdisciplinary Studies in the co-departments of Speech Communication, Human Development and Family Studies, and Statistics presented on March 2, 1992.

Title: Effectiveness of Computerized Communication Treatment for Neurologically Impaired Adults

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The single subject alternating treatment design experiment reported here compared the effectiveness of pencil-and-paper versus computerized communication treatment for neurologically impaired adults. Five stroke patients receiving outpatient speech/language treatment (ages 51-72) served as subjects. One subject completed the experiment as designed and clearly supported the hypothesis that a higher number of correct responses would be produced using the computer generated exercises than the pencil-and-paper version.

Two subjects were unable to demonstrate improvement using the experimental treatment program and the other two subjects were unable to master keyboarding skills necessary to use the computer effectively. However, four out of five subjects preferred using the computer even though it did not

result in improved performance.

Details of specific subjects' performance, and benefits and cautions regarding computer use are discussed. Results suggest that adequate receptive language skills favor effective computer use while impulsivity and visual spatial deficits may be expected to interfere. Careful matching of treatment task to the individual is important; if the task is too easy or too difficult potential benefit of computer use may be masked. The study also supports the finding that computer use is a highly motivating treatment technique for some patients and may be of benefit even if improved task performance does not result.

Suggestions for further research include comparison of computerized versus non-computerized treatment for a greater variety of tasks, careful task analysis of currently available software, examination of techniques for training the mechanics of computer use, examination of specific subject characteristics which correlate with successful use of the computer, and determination of which aspect of computer use, specific feedback or improved motivation, is responsible for improved performance.

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EFFECTIVENESS OF COMPUTERIZED COMMUNICATION TREATMENT  
FOR  
NEUROLOGICALLY IMPAIRED ADULTS

by

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INTRODUCTION

Microcomputer technology is increasingly being applied to a variety of problems in many different fields. The field of communication disorders is no exception. Several books reviewing the use of microcomputers in speech and language pathology and audiology in general, and in aphasia therapy in particular, have appeared in recent years (Schwartz, 1984; Fitch, 1986; Grossfeld and Grossfeld, 1986; Katz, 1986). By and large these authors enthusiastically endorse the use of computer technology in aphasia therapy. Fox (1990) discusses potential advantageous changes in the clinician-patient interaction with computer use. Other authors (Larson and Steiner, 1985), while favorable to the use of computers, emphasize caution and suggest guidelines for assuring that computer use is appropriate in a given situation. More recently, Scherz (1990) also emphasizes the importance of selective application of computer technology.

The use of computer technology has also been enthusiastically promoted in cognitive treatment. Bracy (1983) emphasizes the potential of the computer as a tool in cognitive treatment for improving what he describes as

"Foundations Skills", while cautioning that the presence of a skilled therapist is equally important. He cites consistency, time keeping and data collection capabilities, and ability to set up home-based programs as key advantages of computer based treatment. Bracy et al. (1985) participated in a panel discussion addressing the use of computers in cognitive treatment. They point out that novelty, flexibility, availability and public acceptance have contributed to the rapid introduction of computers into therapy programs, perhaps without careful analysis. Possible advantages are suggested, including the anonymity of making mistakes on the computer and the freeing of clinicians' time from routine drill and quantitative data keeping, allowing more time for qualitative observation. The usefulness of computers in providing home-based treatment when availability of traditional treatment may be limited is reiterated. The lack of experimental studies documenting the effectiveness of computer assisted cognitive rehabilitation is also pointed out. Story and Sbordone (1988), Lynch (1989), Sohlberg and Mateer (1990), and Levin (1991) similarly detail advantages and cautions regarding the use of computers in cognitive rehabilitation.

Despite the proliferation of recommendations for the use of computer technology, few studies have been published which document the effectiveness, advantages, or disadvantages of computer therapy in treating communication

and cognitive disorders. The few existing studies describe computerized therapy in a variety of treatment areas. Seron et al. (1980) and Katz and Nagy (1984) present results of computerized therapy for spelling difficulties, while Mills and Thomas (1981) and Fitch and Cross (1983) describe programs to treat auditory comprehension deficits. Katz and Nagy (1982, 1983, 1985) present several different programs designed to improve reading comprehension. Loverso et al. (1985) present a computerized version of their "verb as core" treatment procedure for eliciting sentences. Each of these studies shows that it is possible to demonstrate improvement over the course of a computerized treatment program with at least some aphasic patients. However, these studies can only be considered as exploratory; they demonstrate the feasibility of computerized treatment, but not any particular advantage over more conventional therapy. In the only study which attempted to compare computerized and non-computerized treatment directly (Loverso et al., 1985), the single patient reached criterion in fewer sessions with traditional clinician-administered therapy than with computerized therapy. Computerized cognitive treatment is described in areas such as visual-spatial tasks (Robertson et al., 1988; Nicely, 1987), memory (Kerner, 1985; Batchelor et al., 1988) and attention (Gray and Robertson, 1989).

Considering the optimistic outlook of these preliminary

studies, it seems reasonable to examine in more detail the specific conditions under which computerized therapy might be beneficial. Larson and Steiner (1985) recommend some guidelines for determining whether to use a computer in a specific application. They suggest that computerized therapy should only be used if the benefits, measured in terms of attainment of specific objectives, can justify the additional expense. This guideline is particularly relevant when considering the goal orientation demanded by providers of third-party payments. They also emphasize that the computer cannot entirely take the place of the human clinician. Although some researchers have expressed enthusiasm for completely computerized long-distance therapy (Fitch and Cross, 1983), the results of Loverso, et al. (1985) tend to corroborate the importance of the clinician-client interaction.

Other clinicians point out that computer use may actually be associated with improved motivation. Despite Larson and Steiner's (1985) proscription that client enjoyment is not a good enough reason to employ computer technology, client enjoyment may significantly affect whether a client actually participates in supplementary therapy activities. As Frydenberg and Wheeler (1986) point out, relatively independent use of a computerized therapy program may result in increased feelings of confidence and control on the part of the client. Katz and Nagy (1982)

also mention the benefit of a more active client role in therapy; in another study (1984) they found that clients were more likely to complete computer-generated than clinician-assigned homework. In the same vein, Odell et al. (1985) suggest that some clients may be more comfortable with computer presentation of difficult tasks because errors are not observed by the clinician. Fox (1990) describes how the clinician-patient interaction can change positively with computer use in therapy. Task presentation and performance feedback are delivered by the impartial computer; the patient takes more responsibility for treatment sessions, while the clinician takes on a partnership role. This author also points out the greatly expanded treatment time made possible when computerized treatment without a clinician present is utilized.

With these recommendations in mind, a useful next step would be to compare supplementary therapy presented on a computer with traditional workbook methods of providing supplementary tasks. Looking at supplementary therapy instead of comparing computer-controlled with clinician-controlled therapy would minimize effects of the difficult-to-quantify clinician-client relationship and simplify interpretation of results.

Grossfeld and Grossfeld (1986) suggest that computer use is especially well-suited to the remediation of reading and writing difficulties. The use of visually presented

material avoids the complication of choosing appropriate hardware and software to attain high quality computer speech. Treadwell et al. (1985) discuss difficulties in using computerized speech with aphasic subjects.

Reading comprehension/recall and scrambled word exercises were chosen for this investigation because of their relevance to functional communication over a broad range of severity levels, and because a relatively simple treatment program was available (in use in the clinical work setting). This study is designed to investigate whether these therapy programs could be presented more effectively on the computer than in a traditional pencil-and-paper format. Specifically, it is hypothesized that subjects will produce a higher number of correct responses, on average, with computer generated exercises than with comparable pencil-and-paper exercises.

## LITERATURE REVIEW

### Aphasia Case Studies

One of the earliest studies describing computer-based aphasia therapy is Seron et al. (1980). While a time-shared mini-computer was used in the study, the procedures described are accessible to current microcomputer technology. Seron et al. (1980) developed a computerized treatment to improve spelling to dictation. While the clinician was still required to present the stimulus, the subjects typed their responses on the computer. If an incorrect letter was typed in, it would not appear on the screen. In this way immediate feedback was given and errors were not visualized (and inadvertently reinforced). The program contained a hierarchy of difficulty in both word choice and cuing/feedback procedures, which were automatically modified based on patient performance. Five aphasic subjects, representing a variety of ages, etiologies and severity of impairment, participated in the program. Performance was assessed with a hand written spelling test of words not included in the therapy program, presented before, immediately after, and six weeks after treatment. All five subjects showed significant improvement at the first post-test; while second post-test scores were somewhat

lower, all were still higher than pre-test scores. Although this paper does not compare computerized and non-computerized therapies directly, the authors do note that four of the subjects had received traditional therapy for their writing disorders previously, with little success.

Katz and Nagy (1984) also describe a computerized spelling task. Since the stimulus in this program is a line-drawing representing a commonly-used noun, word-finding skills are also addressed. The program consists of seven nouns, presented in random order, with a hierarchy of additional cues serving as error feedback. After initial supervision in learning how to operate the computer, clients were able to work on their own. Homework consisting of a printout of error words to be copied could be assigned by the computer. Eight men representing different types and severity levels of aphasia participated in the program. The six patients who completed the program showed improvement on a written confrontation naming task given pre- and post-treatment, and on the computer task itself. These results are again encouraging, but not definitive. In particular, the relative importance of the written homework was not assessed.

Colby et al. (1981) described a word-finding program for a portable computer. While the device was used here as an augmentative communication aid, applications to the therapy situation are obvious. The system is based on the



observation that anomic patients can often retrieve some aspect of the desired stimulus word. Therefore, the computer is programmed to ask a series of questions: topic (multiple choice), first letter, last letter, other letters, "go with" words, and it responds with all words in the stored lexicon which fit those criteria. One case study is presented, but no attempt is made to quantify any improvement in word-finding abilities experienced with the device.

Mills and Thomas (1981) have developed a program to treat aphasics' auditory comprehension deficits. The patient is asked, using a digitized speech signal, to choose one of four items pictured on the screen. Both visual and auditory feedback is provided. As therapy progresses, two and three item sequences must be identified. The authors present results from one patient indicating performance gains for these particular programs, but no objective data suggesting carryover to other treatment tasks or to functional communication.

Improvement of this same patient is more fully described by Mills (1982) in a subsequent paper. He reports that this patient's scores on auditory comprehension portions of the Porch Index of Communication Ability (PICA) and on the Token Test improved during the course of computerized treatment, and that subjective observations suggested improved functional auditory comprehension as

well. Fitch and Cross (1983) describe a computerized auditory comprehension program delivered via telephone to a single subject. Visual stimuli were presented in a booklet, directions issued by the computer over the phone, and responses returned by pushing a key on the touch-tone key pad. The computer then presented verbal feedback. They report successful completion of the program and good acceptance of telephone therapy by this patient, but no quantitative data is presented.

Davidoff and Katz (1985) describe a similar experiment using a telephone answering machine to deliver supplementary auditory comprehension treatment to aphasic adults. Improved listening skills were demonstrated for 6 of 8 subjects. While this experiment did not involve use of the computer, it does illustrate the usefulness of supplementary treatment that is not directly administered by a clinician.

Katz and Nagy (1982, 1983, 1985) have published several papers concerning the use of computers for treating reading difficulties in aphasic patients. They describe the Computerized Aphasia Treatment System (CATS) (Katz and Nagy, 1982), which consists of a diagnostic reading test and reading, spelling, and math treatment tasks. They used a single-subject design with pre- and post-testing to evaluate performance in the treatment tasks. Five subjects with varying types/severity of aphasia completed the program. The Reading Comprehension Battery for Aphasia (RCBA), parts

of the Doren Diagnostic Reading Test of Word Recognition Skills, and their own computerized diagnostic reading test were administered at the beginning and at the end of an 8-12 week treatment period. Scores on individual computerized therapy tasks were also examined. Patients showed some improvement in therapy task scores and scores on the computerized diagnostic test, but not on the standardized tests. Unfortunately, test-retest reliability of the computerized diagnostic instrument has not been assessed. The authors conclude that computer-based therapy is an appropriate supplement for both mildly and moderately impaired aphasic individuals.

A subsequent study (Katz and Nagy, 1983) investigated the use of a computerized therapy program to improve recognition and recall of graphically presented commonly used words. Five adult men with mild to moderate aphasia participated in the program. Sixty-five common 1-5 letter words were presented tachistoscopically, and subjects demonstrated recognition or recall through responses ranging from choosing the word from a multiple choice to typing the entire word. Performance was assessed using an A-B single subject design. At the beginning of the experiment each subject was given a series of reading and cognitive tests. After approximately 5 weeks of traditional therapy (which did not include any reading drills) these tests were repeated. For the next 10 weeks, regular therapy sessions

were supplemented with the computer reading program. At the end of this treatment period, the reading and cognitive tests were repeated for a third time. While subjects improved in their performance on the computer exercises themselves, no change was noted on the pre-/post-reading and cognitive tests. The authors once again conclude that the computer can be an effective therapy tool with aphasic adults. They also examined details of their patients' performance on the computer task in order to explore ways to improve computer therapy programs.

In a later study, Katz and Nagy (1985) applied some of the suggestions for improving computer software derived from results of the previous experiment (Katz and Nagy, 1983) to prepare a computerized exercise to improve reading comprehension at the single word level for severely impaired aphasic adults. This exercise consisted of a series of line drawings, presented one at a time, with two to six words below the picture. The subject simply chose a single number key for the word which represented the picture. Based upon individual performance, the number of multiple choices was automatically increased, kept the same, or reduced. A non-computerized version of the therapy task with six choices per picture was used as a pre-test. Subjects were given access to the computer program for up to sixteen sessions; then the non-computerized test was repeated. Three subjects showed considerable improvement over the experimental

period, while two did not. It is interesting to note that the subjects who made noticeable gains were all diagnosed as Broca's aphasics, while those who did not were labelled as a Wernicke's and a transcortical motor aphasic. The authors conclude that the ability of a computer program to adjust stimulus presentation based on the client's response is valuable. They point out, however, that a particular program, no matter how flexible, still may not be appropriate for every patient.

Steele et al. (1987) describe the use of a computerized visual communication system with a single aphasic patient. This subject was able to master receptive and expressive language tasks using the visual symbol system that he was unable to perform using spoken English. While this study demonstrated a clear advantage in using a visual communication system instead of auditory verbal training, it did not attempt to compare computerized and non-computerized versions of the same system.

Each of the above studies shows that it is possible to demonstrate improvement in a selected task over the course of a specific computerized treatment program with at least some aphasic patients. While they demonstrate the feasibility of computerized treatment, they do not document any particular advantage over more conventional therapy techniques. Loverso et al. (1985) directly compared clinician-administered therapy with computerized therapy.

They used their "verb as core" treatment method, in which verbs and "wh-" questions are employed to elicit actor-action-object sentences. Comparable sets of stimuli, arranged in six levels of difficulty, were prepared for computer and clinician presentation. An alternating treatment design with multiple probes was used with a single subject. They compared the number of sessions required to meet criterion at each level of difficulty with clinician- or computer-administered therapy. This particular patient was able to reach criteria in fewer sessions overall with clinician-administered therapy than with computer-administered therapy.

While this result suggests caution in the wholesale implementation of computerized treatment it must be noted that the difference between levels in number of lessons to reach criterion was greater for computerized therapy, and two levels were terminated without criterion having been reached. If these two levels are omitted from the comparison, the difference between computer- and clinician-administered therapy disappears. The single patient in this study was diagnosed as a Wernicke's aphasic; it is interesting that the Wernicke's aphasic in the Katz and Nagy (1985) study was less successful with the computer format than other patients.

Several other studies, while not actually describing computerized aphasia therapy, are relevant. Odell et al.

(1985) developed a computerized version of Raven's Coloured Progressive Matrices test. They compared the performance of sixteen aphasic subjects with two different administration methods of the computerized version as well as traditional non-computerized administration. They found no differences in mean scores over the three administration conditions. The authors concluded that despite some minor practical difficulties use of the computerized version was appropriate. They recommended that the clinician should monitor testing in order to handle possible computer operation difficulties. They suggested that the chief advantage of computerized test presentation would be the time saved in scoring and the potential for in depth analysis of errors.

Selinger et al. (1987) compared the performance of eight subjects on graphic subtests of the PICA using standard presentation and handwritten responses versus computerized presentation and responses. They found no significant difference in mean scores, but did find that computerized presentation took more time. In this study, the improved legibility did not result in better scores and the authors suggest that the addition of typing to the task may actually result in increased task complexity.

Gigley and Duffy (1982) discuss how the field of artificial intelligence could be of benefit to clinicians working with aphasics. They present a computer model for

language comprehension which can be artificially lesioned to simulate aphasic syndromes. There is, of course, no guarantee that human and machine language processing actually correspond, but interaction between researchers in artificial intelligence and in clinical aphasiology presents a fascinating prospect. Both fields could expect to be enriched by this collaboration.

### Cognitive Case Studies

Case studies involving computerized cognitive therapy also support the usefulness of computerized treatment. Kerner (1985) examined the effectiveness of memory retraining with head-injured adults. He compared a group receiving specific memory retraining programs on the computer, with control groups receiving general computer exposure and no treatment. The experimental group showed significant improvement on a selected memory test given before and after the treatment program, and post-test scores were significantly better than controls.

Fishman (1986) reports on a group study comparing patient's performance in activities of daily living tests (related to dressing, feeding, bathing, grooming, safety/orientation). The group receiving computerized cognitive therapy in addition to conventional occupational therapy showed a significantly faster rate of improvement in the activities tested.



Nicely (1987) conducted a group study comparing performance of chronic alcoholics on several visuospatial tasks after computer-based treatment. The treatment group did show significant improvement compared to controls receiving no specific visuospatial treatment. Fisk-Price (1987) compared performance of chronic alcoholics in abstract reasoning and psychomotor speed and coordination using a group design. Subjects received treatment with a computerized cognitive remediation program, standard non-computerized treatment combined with exposure to computer games, or standard treatment alone. In this study, no significant difference between treatment groups was found.

Another study (Fisher, 1988) examined performance of thirty brain-damaged adults in a hospital day care program in a variety of cognitive skills before and after computer remediation. Subjects' performance improved in most areas after computerized treatment. An exit interview showed that most subjects were positive toward computer use.

Kirsch et al. (1987) describe the use of a microcomputer as a compensatory aid for environmental cuing rather than a provider of cognitive drill. They found that a patient made fewer errors in a cookie baking task with computer-assisted instructions than when following written instructions alone. Robertson et al. (1988), using a multiple-baseline single subject design, were able to show some improvement in visual neglect in three subjects after

computer-delivered treatment. However, they made no attempt to compare computerized versus non-computerized treatment programs.

Batchelor et al. (1988) specifically compared computerized and non-computerized cognitive treatment using a group design. The authors used existing cognitive treatment programs in the areas of memory, attention/speed of information processing, and higher cognitive function. They compared scores on a battery of standard neuropsychological tests before and after treatment and found no significant difference between the two groups. In his commentary at the end of this paper (Batchelor et al., 1988), Munday raises the question of whether computer-assisted treatment may be more advantageous in later stages of cognitive training rather than in the acute phase of treatment described here.

Ruff et al. (1989) compared the efficacy of a structured neuropsychological treatment program which included some computer-assisted treatment with a non-structured treatment approach emphasizing psychosocial adjustment and activities of daily living. They used a group design, comparing performance of forty head-injured subjects on neuropsychological test measures before and after treatment. The group receiving a structured treatment approach did show larger gains in selected areas; however, this difference cannot be attributed to the use of

computerized treatment, since the two treatments differed in other respects as well. Gray and Robertson (1989) showed, in a single-subject multiple baseline design, that performance in attentional function improved with computer based training, but did not compare computerized versus non-computerized training programs.

These preliminary studies describe the use of computerized therapy for different deficit areas, for patients with varied profiles, and as primary or supplementary therapy. They are cause for an optimistic outlook concerning the use of computerized therapy programs for communication and cognitive treatment, but can only be considered exploratory. The small total number of subjects is a serious limitation, especially considering the wide variety in tasks and patient characteristics. These studies do, however, provide the necessary background for considering the advantages and limitations of computer use in aphasia therapy.

#### Advantages and Limitations of Computer Use

Larson and Steiner (1985), while agreeing that microcomputer use in language intervention shows great potential, caution against generalizing results from a few case studies to all clients. They present a list of specific guidelines to help determine if computer use is appropriate. First, they recommend that computerized

therapy should only be used if the benefits, measured in attainment of specific objectives, can justify the additional expense. Client enjoyment alone is not a sufficient reason. They warn against ignoring other advances in therapy, for example, an emphasis on pragmatics, simply because computer software is not available. They also emphasize that the computer cannot take the place of the human clinician entirely. Although some researchers have expressed enthusiasm for completely computerized long-distance therapy (Fitch and Cross, 1983), the results of Loverso et al. (1985) tend to corroborate the importance of the clinician-client interaction.

Larson and Steiner (1985) stress the importance of networking with computer user groups and participating in the decision-making process when equipment is purchased and allocated, as well as sharing data on computer use with other clinicians. Continuing education activities are also important to stay up-to-date on advances in this quickly-changing field. Although the computer can perform certain tasks more quickly, care must be taken that quality is maintained. When using a computerized program with a client, it is important to make sure the client understands the mechanics of using the computer and that computer exercises are integrated into a functional communication program. On the plus side, they note that for some clients the computer may function as a support, allowing the

completion of a task which would otherwise be impossible. Finally, they detail a number of specific problems or concerns with existing computer hardware and software and encourage speech and language pathologists to become involved in writing, or at least planning, intervention software.

Katz (1984, 1986) discusses the selection of treatment software extensively. He points out the need for critical task analysis of existing software. He recommends that to be most effective treatment programs must be capable of being individualized to meet specific patient needs. Unfortunately, much of the existing software does not have this capability. In fact, the lack of appropriate software may be the greatest obstacle limiting the implementation of, as well as research in, computer applications in communication therapy. While Katz expresses concerns about software quality and the lack of definitive research proving the effectiveness of computerized therapy, nevertheless, he remains enthusiastic about its benefits, particularly the possibility of using supplementary computer stimulation to greatly expand time spent in therapy in a cost-effective manner. Rushakoff (1984) brings up another correctable, but important, limitation slowing down the widespread application of computer technology in aphasia treatment. He comments that some of the problem may simply be lack of clinician training in this area.

As some of the case studies cited previously seem to indicate, careful patient selection may be critical to successful computer therapy. Frydenberg and Wheeler (1986) present some patient selection criteria which they believe indicate a greater chance of success with computer therapy. They feel that use of the computer is most appropriate with mild to moderate aphasics exhibiting anomia or reading and spelling impairments. Visual problems, either in acuity or perception, are poor indicators for success with the computer unless special adaptations can be made. Motivation and attention which influence all treatment outcomes will also influence the success of computerized treatment.

Bracy et al. (1985) addressed issues regarding the use of computers in cognitive treatment in a panel discussion originally presented during the Santa Clara Valley Medical Center 8th Annual Conference. Several reasons are suggested by one participant for the enthusiasm regarding computerized treatment, including novelty, flexibility, availability, and public acceptance. Suggested potential advantages of computer use are the ability to provide numerous repetitions and present carefully calculated levels of difficulty as well as safe simulation of complex tasks such as driving, and perhaps less threatening versions of tasks such as math or money management. It is even suggested that in certain situations, patients may prefer to make mistakes "in private" and may appreciate the precision and patience

afforded by the computer. The financial benefit of freeing clinicians to perform tasks which cannot be duplicated by the computer is also pointed out. Another participant emphasizes the usefulness of computerized treatment in home programs, where the computer can provide feedback which would ordinarily be provided by the clinician.

Story and Sbordone (1988) cite similar benefits of computer use in cognitive training including precision of performance data collection, flexibility, and control of parameters in stimulus presentation and feedback, as well as freeing the clinician to attend to the patient's psychosocial issues. They caution however that computer assisted therapy must be matched carefully to specific patient needs. Lynch (1989) cites improvements in computer hardware and software which he feels will increase the usefulness of computers for cognitive rehabilitation.

Engum et al. (1987), while encouraging the use of computer-assisted home programs, caution that use of these programs may prove more frustrating for certain patients or may exacerbate family and behavioral difficulties by clearly pointing out the patient's deficits. The importance of choosing patients and software carefully for computer-based treatment is emphasized. Another participant also emphasizes the importance of considering how well the chosen software matches specific patient deficits, as well as whether family members are supportive of computer use.

Specific patient characteristics which may interfere with computer use are visual deficits, reduced motor skills and speed, reduced concentration, behavioral problems, impulsivity, low tolerance for frustration, or insufficient language skills for a given program. Software program characteristics which should be considered when choosing software are also discussed. These characteristics include flexibility, editing capability, backup ability and available support from the company.

Levin (1991) emphasizes that the computer is only a tool and stresses the importance of considering the treatment model supporting a particular computerized treatment, rather than focusing on use of the computer itself. He suggests that efficacy of treatment must be measured on the basis of whether improvements in specific areas are generalizable. He goes on to review some of the existing efficacy literature and concludes that the evidence is sufficiently promising to encourage further study. He also discusses how computer applications can be related to the particular cognitive retraining model described in this paper.

A number of authors cited previously have addressed the issue of appropriate software selection. Wilson (1983) lists useful software selection criteria as well as general guidelines for use of software with a particular client. Braun et al. (1987) point out the need for normative data



for performance on computer based cognitive rehabilitation tasks and present some preliminary data for a popular series of perceptual-cognitive software. Lynch (1983a) describes a variety of commercially available games and software which are appropriate for cognitive training.

The microcomputer may be especially well suited to remediation of reading and writing disorders. Lynch (1983b) describes the use of a standard word processing program in treating an aphasic patient. He proposes that use of a word processor allows writing treatment to focus on the language impairment without the complicating issue of the fine motor coordination involved in the physical process of writing. In addition, the word processor provides consistent, clear, legible visual feedback and may allow for a more rapid response. The ability to correct errors easily may also make writing tasks appear less intimidating.

Rosegrant (1985) suggests similar advantages in using a word processor combined with speech synthesizers in teaching reading and writing skills to learning disabled students. Specifically she reports the following advantages: separation of development of composition skills from the motoric aspect of handwriting, visual and auditory feedback provided by the screen and speech synthesizing, ease of correcting errors, and the ability to individualize lessons for each student. Malachowski (1986) reports similar benefits in using a word processor to improve writing skills

for a college age head trauma victim. Use of the computer allows a separation of composition from the motoric aspects of handwriting, as well as providing a memory-aid, clear visual feedback, and easy error correction. Bridwell-Bowles (1987), while also enthusiastic about the potential of word processing and computer assisted instruction in teaching writing skills, cautions once again that the technology should not be applied haphazardly and that further study is needed to determine the types of programs which may be most useful. As cited previously, Selinger et al. (1987) did not find significant differences between computerized and standard presentation of graphics subtests of the PICA.

Since a significant proportion of neurologically impaired adults are elderly, it would also be useful to explore acceptance and facility in computer use among this population. Hoot and Hayslip (1983) describe the potential benefits of promoting computer use among normal elderly adults, for example, the opportunity for self-paced learning, and for increased interaction with children in school programs teaching computer skills. Danowski and Sacks (1980) investigated attitudes of elderly adults toward computer use. They introduced residents of an urban retirement center to a variety of computer activities. They found that participants preferred activities with a high degree of interactiveness and that attitudes toward the computer while already generally favorable at the onset of

the experiment, improved after increased exposure, as measured by a pre- and post-treatment survey. They found that large size display screens and characters and a simplified encoding process, the initial presence of a trained staff member to assist with computer use and a small group setting facilitated acceptance of the computer among elderly users.

Drew and Waters (1986) promote the use of video games to improve perceptual motor skills and cognitive functioning in the elderly. In a pilot study with a small sample chosen from residents of a senior apartment complex, the experimental group demonstrated improved scores on the video games, as well as improved performance on a neuropsychological test battery. Subjects also reported improved manual dexterity in their daily activities. These limited studies support computer use with elderly patients and suggest that factors which might inhibit use of the computer, such as unfamiliarity or reduced vision and manual dexterity, can be overcome.

The ability of impaired subjects to learn the mechanics of computer use is also important. Glisky et al. (1986) examine whether memory-impaired patients are able to learn skills needed to operate the computer. They conclude that these patients are able to master the skills necessary for fairly independent use of the computer, although they do so more slowly than controls, and are less flexible in their

use. These results are encouraging when considering independent computer use as supplementary treatment.

Wolf et al. (1987) compared the ability of aphasic and non-aphasic subjects to solve a visual puzzle using the actual wooden object or a computer graphics presentation. They found that aphasic subjects needed more time to complete the task and made more errors when using the computer. The authors propose that either difficulty translating a three-dimensional puzzle to two-dimensional form or difficulty in keyboard manipulation could be responsible for the decreased performance. In either event, these results suggest caution in using the computer with aphasic patients. Nagler et al. (1989a), on the other hand, demonstrate improvement in visual perceptual skills in a single subject after microcomputer training, despite a significant aphasia. The authors cite possible advantages of computer use, including the provision of immediate feedback, more precise and uniform stimulus presentation, and perception of tasks as non-demeaning. Nagler et al. (1989b) also describe the use of a computerized attention/concentration training program with a dementia patient. They were able to show improvement in specific treatment tasks as well as longer time on task, but not decreased general distractibility, after computerized treatment.

## METHODS

### Subjects

Subjects were chosen from among acute onset neurologically impaired adults receiving outpatient speech/language treatment at Oregon Rehabilitation Center, Sacred Heart General Hospital, Eugene, Oregon. Speech/language pathologists providing individual treatment reviewed the experimental program and recommended patients for whom the proposed program appeared to be appropriate and complementary to their current treatment. Final selection was made based on results of administration of baseline measures, as described in the procedures section. Subject demographics are reported in Table 1. Details of the project were discussed individually with each prospective subject and with family members as appropriate. Written consent to participate was obtained from the patients.

### Materials

Selected exercises from a commercially available computerized treatment program (Cognitive Rehabilitation Series by Hartley Courseware), Smith (1984), were chosen as the basis for the experimental program. This software series is mentioned in a recent review (Scherz, 1990) as a

TABLE I

## Subject Demographics

<u>Subject</u>	<u>Age</u>	<u>Sex</u>	<u>Diagnosis</u>	<u>Time Post- onset (years)</u>	<u>Language Status</u>
#1	52	M	Left CVA	7.0	Very mild receptive aphasia, moderate to severe expressive aphasia.
#2	58	M	Left CVA	4.0	Moderate receptive aphasia, moderate to severe expressive aphasia.
#3	72	F	Right CVA	1.5	Moderate to severe receptive aphasia, severe expressive aphasia.
#4	57	M	Right CVA	1.0	Auditory/verbal skills adequate, but impaired visual/perceptual and organization skills.
#5	51	M	Left CVA	1.5	Mild to moderate receptive aphasia, severe expressive aphasia.

popular choice due to its versatility and varying levels of difficulty. The first set consists of a series of reading comprehension and recall exercises. The second set consists of a series of scrambled word exercises. Four levels of difficulty are provided in each series. Additional comparable stimuli were written for each level as needed to accommodate requirements of the experimental design.

The reading comprehension/recall series consists of a single sentence, followed by 1-3 questions about the information in the sentence. Sentence length and number of critical elements in the sentence increase from 4-5 words/one element at the first level to 8-17 words/four elements at the fourth level. Questions must be answered from memory with accurate spelling. Levels 1-3 contain 10 questions each in groups A and B, level 4 contains 12 questions each in groups A and B. The scrambled word series begins with 3-5 letters, multiple choice format at level 1; 3-4 letters, no choices at level 2; 5-6 letters, multiple choice format at level 3; 5-6 letters, no choices at level 4. There are ten questions each in groups A and B at each level.

Questions were randomly assigned to baseline, group A, or group B. Both group A and group B questions can be presented in either computer or pencil-and-paper formats. Baseline measures were provided for levels 1 and 2 in each series, so that subjects could begin the program at either

level of difficulty. The complete set of stimuli at each level are presented in Appendix I. Questions for computer presentation were then transferred to the "Create Your Own Lessons" disk (by Hartley Courseware). This program contains the same format as the Cognitive Rehabilitation series but allows the user to enter original stimuli. An Apple IIe computer was used for the computer presentation.

In the computer mode, instructions first appear on the screen and are also presented verbally by the experimenter. Next, the first stimulus sentence appears. The subject controls timing of stimulus presentation by pushing the "return" key and no attempt was made to control length of time subjects viewed the stimulus sentence or answers. After viewing the stimulus sentence and pushing the "return" key, the sentence disappears from the screen and a question appears. Subject then types the answer to the question. Answers may be revised as much as the subject wishes before the "return" is pushed again. The next screen indicates whether the answer is correct or incorrect. If the answer is correct, patient is given positive reinforcement such as "good work", "nice job" and the next screen provides a new stimulus sentence or another question. If the answer is incorrect, a "help" screen is offered. A portion of the original stimulus sentence giving only the first letter of the answer is usually displayed. For numerical answers, cue consists of a more than/less than or before/after statement.



In the next screen the cue disappears and the original question is repeated. This time if an incorrect answer is given the next screen displays the incorrect answer crossed out with the correct answer appearing below it. The next screen provides a new stimulus sentence or another question. Subjects were assisted with mechanics of operating the computer (location of "return" and "back-up" keys, etc.) as often as necessary.

Stimuli for the pencil-and-paper presentation were printed in enlarged print format using WordPerfect 5.0 on an IBM compatible computer and a Star NX-1000 near letter quality printer on 8.5 by 11 inch sheets of paper. Spacing and line breaks were set up to match the appearance of stimuli on the computer screen as closely as possible. Heavy weight 24# paper was used for increased opacity. Sheets were presented to subjects in a 3-ring binder.

In the pencil-and-paper mode, instructions are given on the first page of the notebook and are also presented verbally by the experimenter. The first stimulus sentence appears on the next page with the corresponding question on the following page. As with the computer mode, subjects control rate of stimulus presentation. Subjects are reminded, if necessary, that they may not turn back to review sentences once they turn to the question page. Subjects may take as much time as they wish and self correct answers until they turn to the following page, containing

either a new stimulus sentence or another question. No feedback is given regarding accuracy of answers in this mode.

### Procedures

Baseline measures were administered to each prospective subject identified through initial screening by individual therapists. All baseline questions were presented in the pencil-and-paper format. Subjects were first given five questions at level 1 of both series. Criterion for inclusion in the study was that subjects exhibited at least minimal understanding of the requirements of the task, but scored 60% or less on the first set of baseline questions. If a subject exceeded criterion on either series, five questions at level 2 were then presented. If the subject passed criterion at level 2, the program could be initiated at this level.

If a subject passed criterion and agreed to participate further arrangements were made to meet with the subject on a regular basis either before or after the regularly scheduled treatment session. During the next two sessions, two additional sets of five baseline questions each were presented in the pencil-and-paper format. Random selection was used to determine which group of questions (A or B) would be presented as the computer task and which would be presented as the pencil-and-paper task for the first

subject. Group A questions were assigned to computer presentation and group B questions to pencil-and paper presentation for Subject #1. Subsequent subjects were alternately assigned to group B or group A for computer presentation, that is, Subject #2 received computer presentation of group B questions and pencil-and-paper presentation of group A questions, while Subject #3 received computer presentation of group A questions.

The experimental design is a modified alternating treatments design (Barlow and Hayes, 1979; McReynolds and Kearns, 1983). Each subject completes both the computer and pencil-and-paper exercises in every session, and performance between these two formats is compared, rather than comparison with the baseline performance. Order of presentation (computer versus pencil-and-paper) is counter balanced during each session to control for possible sequence effects, with order for first session randomly assigned.

During each experimental session, the subject completed one set of questions in each mode (computer and pencil-and-paper) at the same level. In subsequent sessions, the same matched set of questions was repeated until criterion was reached. Criterion was reached under several conditions: 1.) 100% both modes in one trial; 2.) 100% in one mode and 90% in other mode in one trial; 3.) 90% in both modes in two trials; 4.) 100% in one mode in three trials, regardless of

performance level in the other mode. Once criterion was reached, the subject advanced to the next level and proceeded in the same fashion.

Only one subject was able to complete all four levels as outlined in these procedures. For other subjects, participation in the experiment was terminated when it was determined that their level of performance would not allow them to reach criterion in a timely fashion, or for other reasons as outlined in the results section. At the conclusion of each subject's participation, he or she was asked a series of questions relating to use of the computer (see Appendix II).

### Analysis

It is hypothesized that subjects will produce a higher number of correct responses, on average, with the computer generated exercises than with the pencil-and-paper exercises. The number of correct answers in each mode during each session was tabulated and compared graphically and statistically if appropriate. Statistical analysis was carried out using the Wilcoxon signed ranks test (Sincich, 1985; Edgington, 1982; Pratt and Gibbons, 1981).  $H_0$  equals no difference between number correct using computer versus paper.  $H_a$  equals scores for computer presentation higher than scores for pencil-and-paper presentation. A one-tailed test was used with alpha equal to 0.005.

## RESULTS

Subject #1 met entrance criteria for the reading comprehension series, but not for the sequencing series. (He scored 100% and 80% respectively in levels 1 and 2 baselines.) Number of correct answers during each session is presented in Figures 1-4. Subject #1 was the only subject able to reach criterion in all four levels. Visual examination of the results shows that this subject's performance supports the hypothesis that a higher number of correct responses would be produced using the computer generated exercises than the pencil-and-paper version. Statistical analysis using the Wilcoxon signed ranks test was also performed on results from levels 2-4, comparing pencil-and-paper with first trial computer scores. Level 1 contained too few data points for meaningful statistical analysis ( $n=2$  after removing ties). The Null hypothesis (i.e. no difference between number correct using computer versus paper) was rejected for levels 2-4. For level 2,  $n=9$ ,  $T^-=0$ , and  $p=0.002$ . For level 3,  $n=9$ ,  $T^-=0$ , and  $p=0.002$ . For level 4,  $n=12$ ,  $T^-=2$ , and  $p=0.0007$ .

Subject #2 also met entrance criteria for the reading comprehension series, but not for the sequencing series (80% and 100% baseline scores for sequencing levels 1 and 2 respectively). Number of correct answers during each

session is presented in Figure 5. Subject #2 showed little difference between computer and pencil-and-paper scores, and never met criteria to progress beyond level 1. Analysis using the Wilcoxon signed ranks test confirms no significant difference between computer and pencil-and-paper scores. Participation in the experiment was terminated due to lack of improvement in first level exercises, combined with subject's discharge from regular treatment which made further participation inconvenient for this subject.

Subject #3 met entrance criteria for the reading comprehension series but appeared unable to understand the sequencing task. It was determined after the first post-baseline session that this subject was not able to complete ten questions in each format during one session, so the procedure was altered so that only five questions in each format were presented. Results are shown in Figure 6. It was planned that after criterion was reached with the first five questions in level 1, the second set of level 1 questions would be presented. However, this subject did not reach criterion (or show much improvement in performance) after ten sessions. Therefore, participation in the study was terminated at that time, as it was felt that continuing would become increasingly frustrating. This subject also showed little difference between computer and pencil-and-paper performance, although there was a tendency to correct some errors after receiving feedback from the computer.

Analysis using the Wilcoxon signed ranks test shows no significant difference between computer and pencil-and-paper scores.

Subject #4 met initial entrance criteria for both the reading comprehension and sequencing tasks. (Sequencing baseline, level 1, 20%, reading comprehension baselines, level 1, 60%, 100%, 100%.) As with Subject #3, it soon became apparent that it was not possible to complete all twenty questions in each session, so only five questions were presented in each format. Unfortunately, this patient was not able to master use of the computer keyboard or to recognize and correct keyboarding errors. In three trials, he scored 100% in pencil-and-paper format and 0% on first try in computer format. Participation was then terminated.

Subject #5 was unable to perform the reading comprehension tasks, but scored 100% on the level 1 sequencing baseline. He passed criteria for inclusion at level 2 sequencing (with scores of 40%, 20%, 40%) and began the program at that level. Unfortunately, this subject had great difficulty attempting to use the computer. He answered three out of ten questions correctly on the pencil-and-paper exercise but was unable to proceed past the first question using the computer format. This subject appeared to be unable to match lower case letters appearing on the screen with upper case letters on the keyboard.

Participation in the study was terminated, since it appeared

that this subject would require extensive practice with the computer before meaningful participation would be possible. Subjects' responses to computer use based on answers to exit questions will be presented in the discussion section.

In summary, two of the five subjects were unable to use the computer effectively due to inability to master sufficient keyboarding skills. Two subjects were terminated from the experiment at the first level due to inability to demonstrate improvement in either presentation mode after ten to eleven sessions. Only one subject completed the experiment, reaching criterion in all four levels. This subject's performance clearly supported the hypothesis that a higher number of correct responses would be produced using the computer generated exercises.



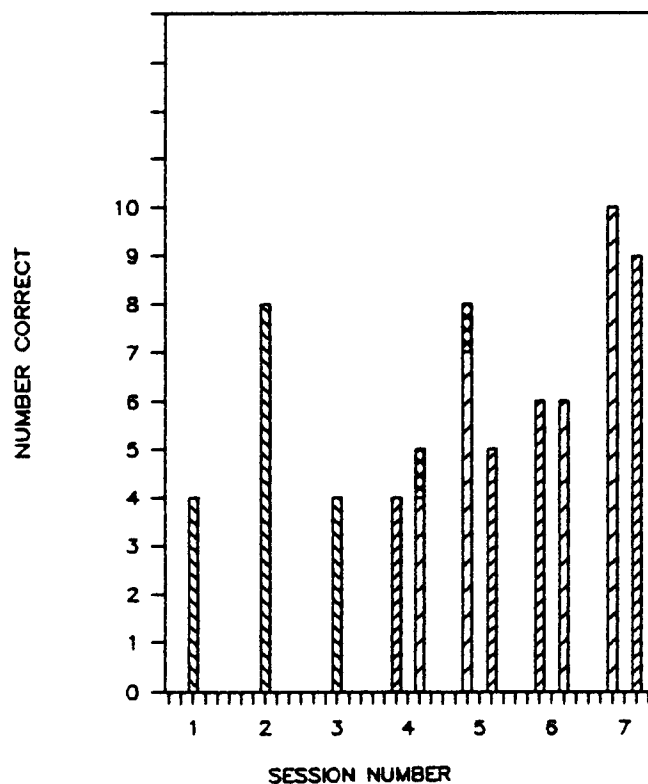


Figure 1. Subject #1, Baseline and Level 1. Number of correct responses by session number. Sessions 1-3 represent baseline scores times two. Bars are arranged according to order of presentation within each session. Maximum score equals ten.

- Baseline scores.
- Pencil-and-paper scores.
- Computer scores; first trial.
- Computer scores; improvement with second trial.

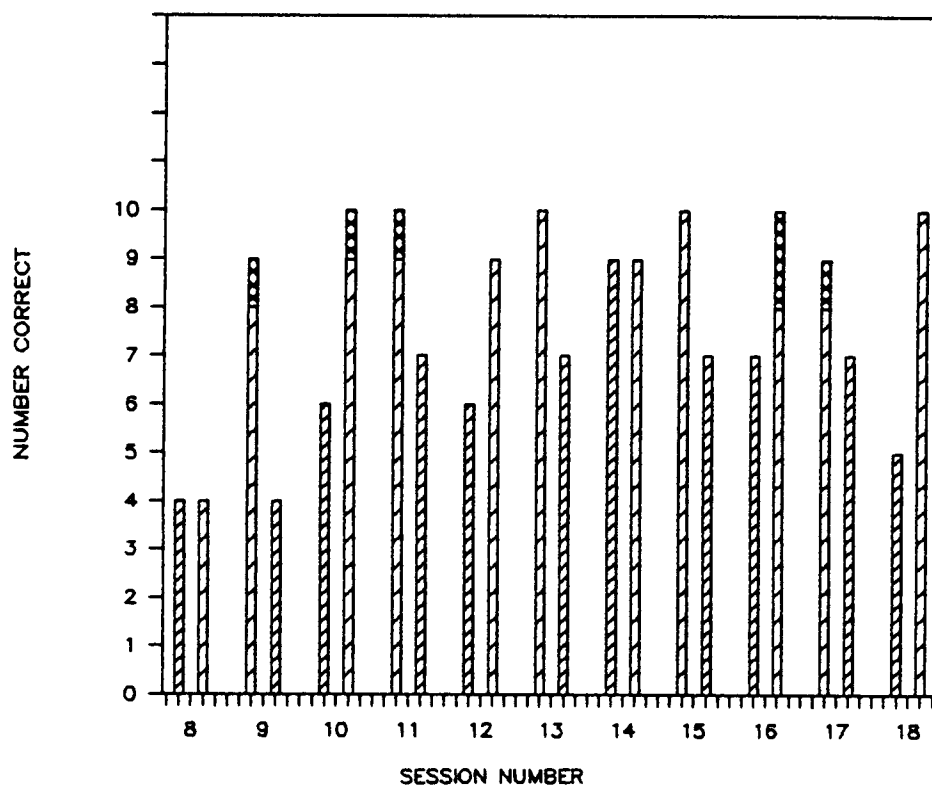


Figure 2. Subject #1, Level 2. Number of correct responses by session number. Bars are arranged according to order of presentation within each session. Maximum score equals ten.

- ▨ Pencil-and-paper scores.
- Computer scores; first trial.
- ▩ Computer scores; improvement with second trial.

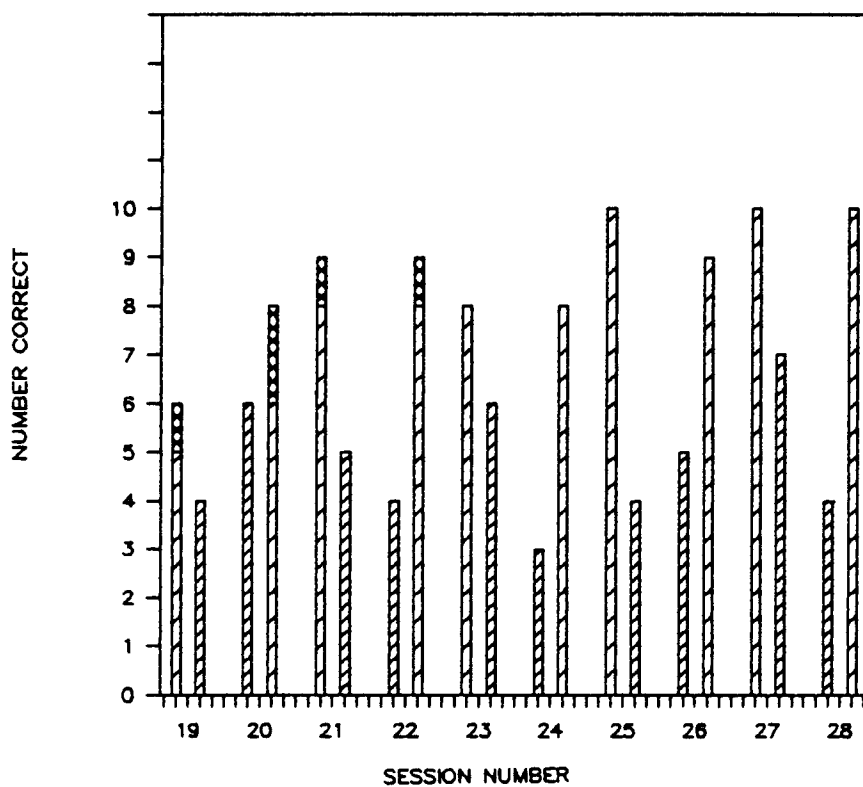


Figure 3. Subject #1, Level 3. Number of correct responses by session number. Bars are arranged according to order of presentation within each session. Maximum score equals ten.

- ▨ Pencil-and-paper scores.
- Computer scores; first trial.
- ▩ Computer scores; improvement with second trial.

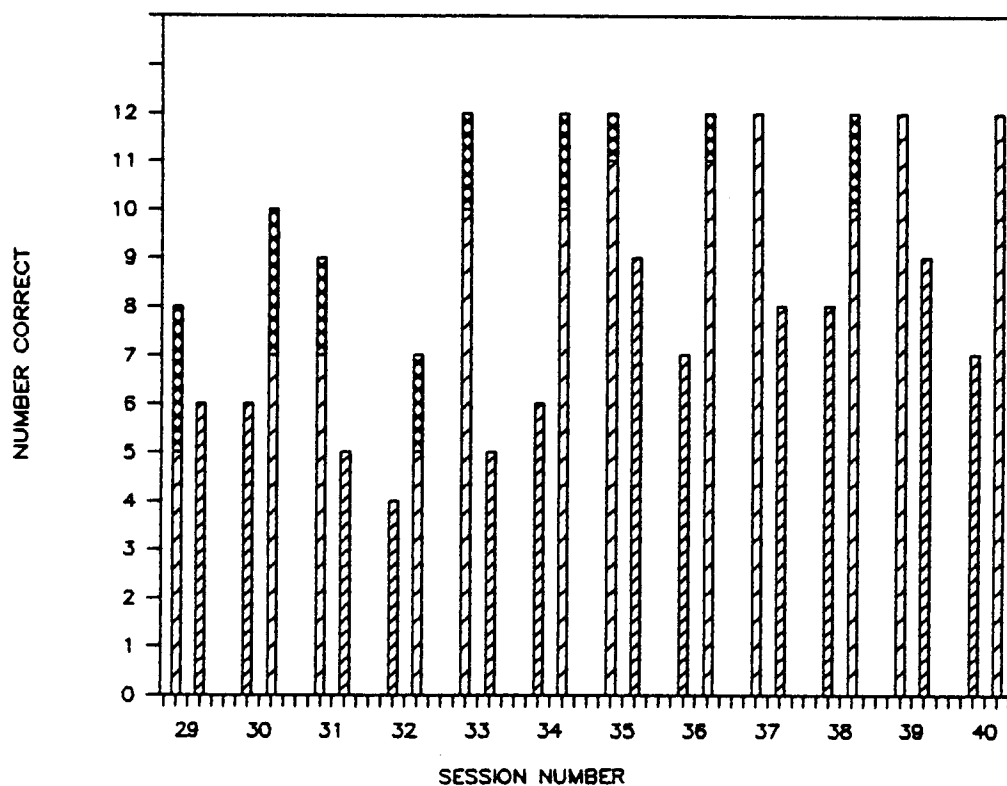





Figure 4. Subject #1, Level 4. Number of correct responses by session number. Bars are arranged according to order of presentation within each session. Maximum score equals twelve.

-  Pencil-and-paper scores.
-  Computer scores; first trial.
-  Computer scores; improvement with second trial.

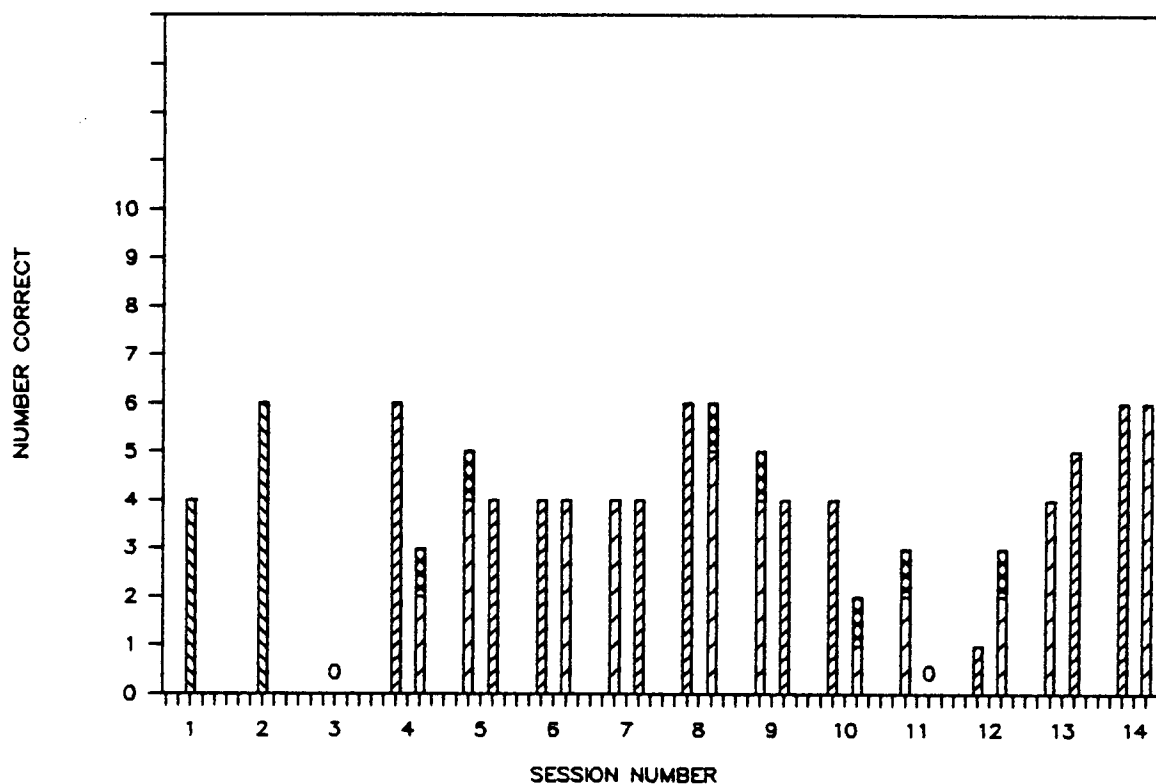






Figure 5. Subject #2, Baseline and Level 1. Number of correct responses by session number. Sessions 1-3 represent baseline scores times two. Zero values are indicated by a "0" in the bar position. Bars are arranged according to order of presentation within each session. Maximum score equals ten.

-  Baseline scores.
-  Pencil-and-paper scores.
-  Computer scores; first trial.
-  Computer scores; improvement with second trial.

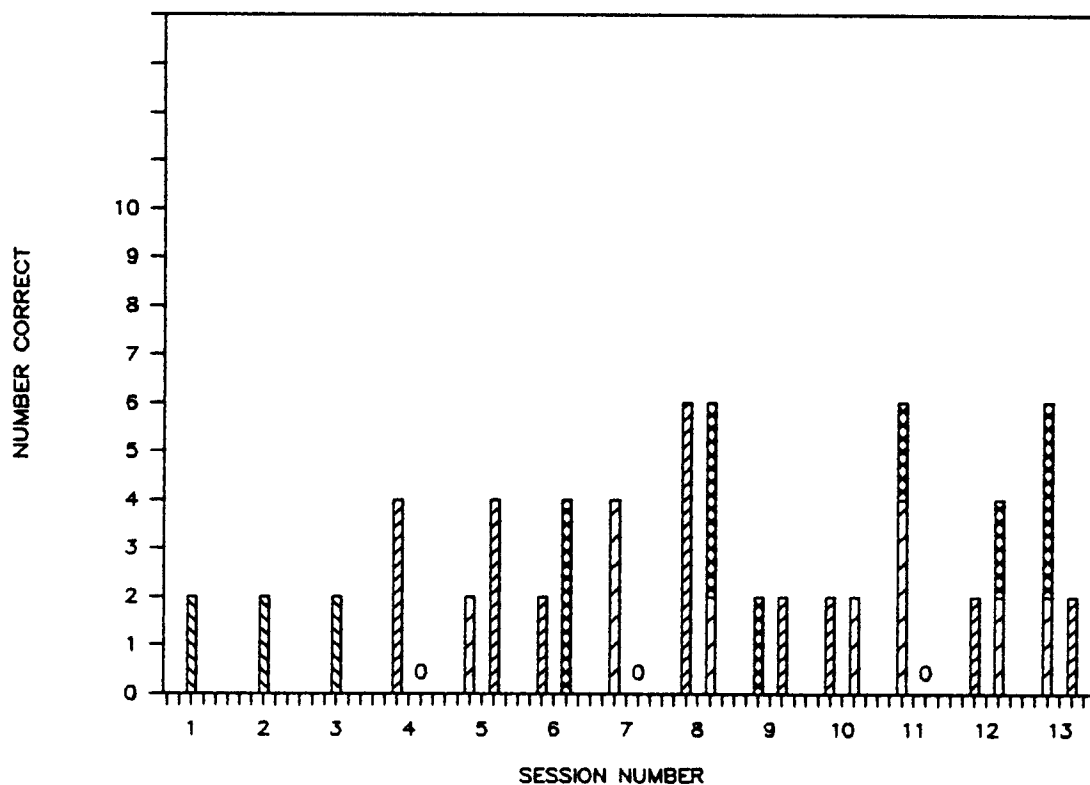






Figure 6. Subject #3, Baseline and Level 1. Number of correct responses times two by session number. Sessions 1-3 represent baseline scores times two. Zero values are indicated by a "0" in the bar position. Bars are arranged according to order of presentation within each session. Maximum score equals ten.

-  Baseline scores.
-  Pencil-and-paper scores.
-  Computer scores; first trial.
-  Computer scores; improvement with second trial.

## DISCUSSION

### Specific Subject Performance

The experiment reported here, as the previously cited study by Katz and Nagy (1985), yielded mixed results. Only one subject clearly supported the hypothesis that a higher number of correct responses would be produced with the computer generated exercises. Interestingly, this same subject was also the only one who made progress in the treatment task. He was able to reach criterion and proceed through all four levels. In addition, this subject's regular therapist reported general improvement in his spelling skills, even though spelling was not a targeted area in regular therapy sessions. Several other subject characteristics stand out: this subject had the best receptive skills, was the longest time post-onset, and required the least amount of cuing regarding the mechanics of using the computer, at least partially fulfilling the patient selection criteria proposed by Frydenberg and Wheeler (1986).

In observing this subject during the sessions, he appeared more likely to carefully review and attempt to self-correct his computer responses than his pencil-and-paper responses. It should be noted that throughout all

difficulty levels the majority of incorrect responses involved spelling rather than comprehension or recall errors, although on occasion, this subject would mix up "wh-" questions at the higher levels. Perhaps the clear and consistent feedback provided by letters on the computer screen, as opposed to the harder-to-read answers written by hand, facilitated perusal and self-correction as discussed by Lynch (1983), Rosegrant (1985), and Malachowski (1986).

In addition, the immediate feedback regarding accuracy of answers, and the chance to try again, may have been motivating. This subject frequently appeared to recognize that handwritten answers were incorrect, but was less likely to persevere at making changes. He also indicated that he preferred working on the computer, and also recognized that his performance was better on the computer. In fact, this subject expressed enthusiasm for continuing to work with the computer during his regular therapy sessions at the conclusion of the experiment.

Subject #2, while not supporting the hypothesis, was the second most successful in terms of being able to participate in the experiment as originally designed. It is interesting to note the characteristics shared by subjects #1 and #2. Both are longer time post-onset (well past the expected period of spontaneous recovery) left CVA's, with expressive skills significantly more affected than receptive skills, and little, if any, neglect or visual perceptual



problems remaining. It should be noted that during the experimental period, Subject #2's performance plateaued or declined in regular treatment sessions as well, and that family issues (which resulted in extended absence) and changes in medication may have contributed to the decline.

Subject #2 was also observed to carefully review and attempt to correct computer responses, but was not as successful as Subject #1 in these attempts. As with Subject #1, most error responses involved spelling rather than recall, and Subject #2 had particular difficulty as word length increased. It would have been interesting to repeat the experiment with target responses controlled for length and spelling difficulty. Under such conditions, Subject #2 may have been able to proceed through the program at a rate allowing for better comparison of presentation modes. Subject #2 was the only participant who preferred the pencil-and-paper format to the computer, although he accurately recognized that his performance was about the same with either presentation method.

Subject #3 and Subject #4 appeared less well matched to the chosen treatment task as well as to use of the computer. It should be noted that both of these subjects experienced right rather than left CVA's, with the resultant increased impulsivity and visual perceptual problems cited as negative indicators for successful computer use by Frydenberg and Wheeler (1986) and Engum et al. (1987). Subject #3

exhibited the most severe receptive difficulties, and showed an unusual combination of deficits (i.e. a significant aphasia combined with more predictable right hemisphere deficits). She required extensive process cuing for both pencil-and-paper and computer presentation to reduce impulsivity. For example, it was necessary to talk through the instructions for each question: "Read the sentence", "Now turn the page", "Now read the question", or "Push return" and "write (or type) your answer". At times tactile cues such as taking pencil from subject's hand while she was reading next stimulus were required. During regular therapy sessions, this patient also showed a high degree of impulsivity and poor error detection and correction. Although this subject's performance did not warrant completion of this experiment as designed, she did show some tendency to correct errors when given feedback by the computer, and was more likely to react positively when errors were pointed out by the computer instead of another person, as suggested by Bracy et al. (1985).

Subject #4 exhibited the least severe language deficits, but the most significant neglect and visual perceptual problems. While he quickly mastered the reading comprehension/spelling task using a familiar pencil-and-paper format, he was unable to overcome impulsivity and visual perception problems sufficiently for successful computer use. He typed in answers quickly and did not

appear to recognize errors. Similarly, Selinger et al. (1987) report that a single right hemisphere subject exhibited slightly better performance in handwritten than computer presentation of graphics subtests of the Porch Index of Communication Ability, and spent approximately equal time to complete handwritten and computer tasks, while subjects with left hemisphere lesions tended to require a significantly longer time to complete the computerized task, but also received slightly higher (though not significantly higher) scores on the computer. Curiously, both Subject #3 and Subject #4 indicated that they preferred working on the computer and felt that performance was about the same whether they used the computer or the pencil-and-paper format, supporting the suggestion that computer use in itself may be a motivating factor for some subjects.

Subject #5 began with the most severe reading deficit. In fact, he was unable to perform the reading comprehension task at all. Unlike the two subjects with right hemisphere involvement, this left hemisphere involved subject did not exhibit a high degree of impulsivity which interfered with effective use of the computer. On the contrary, when uncertain of a response, he was unable to make a "guess" and continue. Although it was not possible to determine the specific reason for this difficulty due to the subject's severe expressive aphasia, it appeared that at least part of his inability to complete this task was related to

difficulty translating between upper and lower case letters.

### Benefits of and Cautions Regarding Computer Use

In summary, this study supports the enthusiasm for using the computer as a supplemental therapy mode for some patients, but also reinforces many of the cautions which have been raised. Not everyone who is able to perform a given language task on paper will successfully transfer to using the computer to perform the same task. Factors which appear to favor successful use of the computer with relatively little training include good receptive language skills, adequate visual spatial abilities, and lack of impulsivity.

However, the very factors which tend to interfere with computer use, such as impulsivity and visual perceptual problems, may be amenable to direct intervention with appropriately designed computer programs (for example, see studies by Nicely, 1987; Robertson et al., 1988). The immediate impartial feedback provided by the computer could be a valuable tool in addressing impulsivity and visual perceptual problems separately from language deficits. Use of the computer would allow coupling of visual and auditory feedback, and measurement or control of response time, without direct involvement of the clinician. This would provide additional practice outside of treatment sessions or free the clinician to make subjective observations during

treatment.

Several subjects in this study continued to require frequent cuing for the mechanics of using the computer indicating that specific training protocols for independent use of the computer may be necessary for some subjects. This points out the need for direct observation of how a given subject interacts with the computer before any home program is provided. Larson and Steiner (1985) and Engum et al. (1987) suggest similar cautions regarding wholesale application of computerized treatment programs.

The desirability of an editing option to modify stimuli in commercial programs (as recommended by Katz, 1984, 1986 and Engum et al., 1987) is also supported by the wide range of responses among subjects who met initial criteria for participation. The program chosen for this study was clearly in the therapeutic range for only one subject, and it was this subject who received higher scores when using the computer. If the treatment task had been modified for each subject so that it was in the therapeutic range; that is, subjects scored 60% or less initially, but were able to show improvement over three to six trials, perhaps the advantage of using the computer observed with Subject #1 would have been replicated with other subjects.

On the negative side, custom preparation of computer exercises can be prohibitively time consuming for the clinician. It would be important for editing to be as quick

and efficient as possible. Programs which contained large data bases of possible stimuli which could be selected according to multiple criteria would be most useful. For example, if the reading comprehension and recall exercise used in this study contained a set of one hundred questions at each level, which could be sorted according to grade level of reading vocabulary, word use frequency, and grade level and word length of response, it would be much more practical to modify the program for each individual.

The overall positive response to computer use even when not "successful" in terms of increased accuracy supports the suggestion that incorporating work on the computer into homework assignments may be motivating. The two subjects in this study who exhibited impulsivity which interfered with use of the computer for higher-level tasks were nonetheless very enthusiastic about their opportunity to work on the computer. A program designed to address error detection and correction techniques within a relatively easy language task might be received with enthusiasm if it was combined with the chance to develop some mastery of computer technology. The same program as a clinician-controlled pencil-and-paper exercise would be much more likely to be viewed as frustrating or boring.

Despite the caution by Larson and Steiner (1985), improved motivation alone may be worth the expense of using the computer if it means homework is completed

enthusiastically rather than ignored. Given the restraints imposed by third-party payers, home-based computerized treatment combined with less frequent direct treatment sessions has the potential to greatly extend the time over which effective treatment services can be provided (see Bracy et al., 1985; Story and Sbordone, 1988).

### Suggestions for Further Research

Further research should include direct comparison of computer versus non-computerized treatment with a greater variety of tasks including both independent and clinician-mediated treatment. Results of this study suggest that it is important to carefully match experimental tasks to each specific subject. In particular, the possibility of observing greater accuracy when using the computer compared to pencil-and-paper is probably more likely if a subject is able to show improving performance in the experimental task over a reasonably short period of time; for example, three to six trials. If the task chosen is either too easy or too difficult, potential advantages of computer use may be masked.

While reading and spelling tasks were used in this study, it would be useful to examine whether an advantage in computer use could be demonstrated with other types of tasks, especially those relating to attention and error detection skills. The program used in this study was of

moderate difficulty. Future research should also include investigation of reading and spelling tasks over a larger range of difficulty.

Careful task analysis of existing software programs and direct comparison of programs purporting to address the same skills would also be welcome. For example, the reading program used in this study is advertised as a program for working on recall of written information, but actually involves mastery of reading comprehension, recall, spelling and keyboarding skills. This program might be contrasted with a hypothetical program which relied on a multiple choice single keystroke response indicating simply which sentence had previously appeared on the screen, rather than requiring decoding of "wh-" questions. A compilation of such detailed information for commercially available software would be useful to both clinicians and researchers.

Examination of alternative techniques for training independent use of the computer would also be helpful. Several subjects in this study showed some promise for computer use but required more extensive training than the experimental protocol allowed. Future research could help delineate which skills were needed to begin using the computer successfully and identify compensatory techniques for training individuals who experienced difficulty mastering traditional keyboarding skills, or ways in which to modify programs so they were easier to use.



Single subject and group studies examining whether specific subject characteristics were correlated with successful computer use would also be helpful. This study suggests that type and severity of aphasia, presence of impulsivity or visual spatial deficits, and attitude toward computer use influence computer performance. It would be important to carefully match treatment tasks to each subject as described previously, with clear improvement in the experimental task demonstrated over the course of the experiment, to be able to separate the influence of subject characteristics. Information regarding subject characteristics, task analysis of software, techniques for training mechanics of computer use, and type of task most amenable to computer presentation could then be combined to generate guidelines to determine whether a given subject would benefit from a computerized treatment program.

The role of specific feedback should also be examined further. The present study does not determine which aspect of computer use was most beneficial. Improved visual feedback with printed rather than handwritten answers, improved motivation due to immediate knowledge of errors, or simply the subject's positive attitude about computer use could have contributed to the improved performance noted with Subject #1. The improved performance of one subject and general positive response to using the computer of the others should certainly encourage speech-language

pathologists to become more active in applying computer technology and developing and testing new software to use with their clients.

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## APPENDICES

## APPENDIX I

## Treatment Program Stimuli

## Reading Comprehension Recall, Level 1

## Baseline 1

1. The coat is brown.  
What color is the coat?
2. She left after lunch.  
When did she leave?
3. We will leave on Thursday.  
When will we leave?
4. Bob moved to Michigan.  
Where did Bob move?
5. May painted the kitchen yellow.  
What color did may paint the kitchen?

## Baseline 2

1. I am baking a pie.  
What am I baking?
2. Beth sat down.  
Who sat down?
3. The coffee is too cold.  
What is too cold?
4. Sam is ready for lunch.  
Who is ready?
5. Their new car is blue.  
What color is their car?

## Baseline 3

1. She lives on Roselawn.  
What is the name of her street?

2. It is in the sink.  
Where is it?
3. Mark is building a gate.  
What is Mark building?
4. We made waffles for breakfast.  
What did we make?
5. Alice works in the cafeteria.  
Who works in the cafeteria?

Set A

1. Our trip is in December.  
When is our trip?
2. The water is too hot.  
What is too hot?
3. The car is blue.  
What color is the car?
4. Lisa is going home.  
Who is going home?
5. They swim in the lake.  
Where do they swim?
6. They went to Bend.  
Where did they go?
7. It always snows in January.  
When does it always snow?
8. Mary went with Jim.  
Who went with Jim?
9. Debbie met her brother John.  
Who met John?
10. It always rains in November.  
When does it rain?

Set B

1. They close at 5:30.  
When do they close?
2. We ride in the park.  
Where do we ride?

3. I saw a policeman.  
Who did I see?
4. Lunch is served at 11.30.  
When is lunch served?
5. They visited their uncle.  
Whom did they visit?
6. Mary was born in Kansas.  
Where was Mary born?
7. Lynn is studying weaving.  
What is Lynn studying?
8. They all like to jog.  
What do they like to do?
9. Susan went to the drugstore.  
Where did Susan go?
10. They are making baskets.  
What are they making?

### Reading Comprehension Recall, Level 2

#### Baseline 1

1. Yellow roses filled the garden.  
What kind of flowers were they?  
What color were the flowers?
2. Sam went to the park on Saturday.  
Who went to the park?  
When did Sam go?
3. The pink shoes are in the box.  
Where are the shoes?  
What color are they?

#### Baseline 2

1. Your brown coat is in the hall closet.  
What color is the coat?  
Which closet is the coat in?
2. Keith bought new shoes at the mall.  
Where did he get the shoes?  
Who bought the shoes?

3. Alice bought Jane a book for her birthday.  
Who bought the present?  
What did she buy?

Baseline 3

1. The Christmas party starts at 7.30.  
What kind of party is it?  
When does the party start?
2. May cooked eggs for lunch.  
Who cooked lunch?  
What did May cook?
3. Jan went to Mexico in March.  
Where did Jan go?  
When did she go?

Set A

1. My dog, Bo, is sleeping on the couch.  
What is my dog's name?  
Where is Bo sleeping?
2. Steve bought it for 25 cents.  
How much did it cost?  
Who bought it?
3. Flight 610 arrives at 8:00.  
When does it arrive?  
What is the flight number?
4. Flora went downtown to buy a card.  
Who went downtown?  
What did she buy?
5. The baseball game starts at 6:00.  
What kind of game is it?  
When does it start?

Set B

1. The kitchen clock says 6:00.  
What time does the clock say?  
Where is the clock?
2. The Carsons travel in April.  
Who travels?  
When do they travel?

3. John gave Alan a surprise birthday party.  
Who was the party for?  
Who gave the party?
4. Jim bought a blouse for Stacy.  
What did Jim buy?  
For whom did he buy it?
5. They will go to the airport at 3:30.  
Where will they go?  
When will they go?

Reading Comprehension Recall, Level 3

Set A

1. The mailman left a package on the front porch.  
Who left the package?  
Where did he leave the package?
2. Beth has a poodle named Sam.  
What is the dog's name?  
Who owns the dog?
3. Tom put the white towels in the washing machine.  
What color were the towels?  
Who put the towels in the washing machine?
4. You have a dentist appointment on Friday at 10:00.  
What day is your dentist appointment?  
What time is your dentist appointment?
5. Joel got his hair cut last Tuesday.  
Who got a haircut?  
When did he get his hair cut?

Set B

1. I bought shampoo at Brown Drugstore today.  
What did I buy?  
Where did I buy it?
2. On Tuesdays, Denise works until 7:00.  
Who works until 7:00?  
What day does she work until 7:00?
3. Last winter Mike went to Florida.  
Where did he go?  
When did he go to Florida?

4. Linda said the turkey would be ready at 6:00.  
What time should the turkey be ready?  
Who said the turkey would be ready at 6:00?
5. Bob celebrated his 18th birthday in October.  
How old is Bob?  
When did Bob turn 18?

Reading Comprehension Recall, Level 4

Set A

1. John rode his bicycle 7 miles to work on Friday.  
How far did he ride to work?  
Who rode to work?  
When did John ride his bicycle to work?
2. Ken played poker on Tuesday at Bob's house.  
What did he play?  
Where did he play?  
Who played poker at Bob's house?
3. Harry invited the Browns for dinner on Saturday.  
Who invited them?  
Who did Harry invite?  
On what night did Harry plan to have the Browns over?
4. Sue invited her cousins to a picnic on Friday.  
Who was invited?  
When will they come?  
To what were they invited?

Set B

1. Stan can't go bowling on Thursday night because he has to watch the kids.  
Who can't go?  
Where was Stan supposed to go?  
When was Stan supposed to go bowling?
2. Sam drives a bus downtown on weekends to make some extra money.  
Who drives the bus?  
When does he drive a bus?  
Where does he drive a bus?



3. The tailor was closed for the first 2 weeks in August while the owners were on vacation.  
What was closed?  
How long was it closed?  
During what month was it closed?
4. Carol lives on Charles Street in a two story red brick house.  
Who lives there?  
What street does she live on?  
What is her house made of?

### Scrambled Words, Level 1

#### Baseline 1

1. Unscramble the letters:

klim

1. climb
2. milk
3. link

2. Unscramble the letters:

atlh

1. tail
2. halt
3. tall

3. Unscramble the letters:

orw

1. row
2. war
3. raw

4. Unscramble the letters:

alts

1. stale
2. stall
3. last

5. Unscramble the letters:

kwla

1. walk
2. look
3. wall

## Baseline 2

1. Unscramble the letters:  
tpa

1. art
2. top
3. pat

2. Unscramble the letters:  
ryc

1. rye
2. you
3. cry

3. Unscramble the letters:  
lnia

1. lane
2. mail
3. nail

4. Unscramble the letters:  
ncih

1. chin
2. neck
3. pick

5. Unscramble the letters:  
omlo

1. loom
2. mole
3. loam

## Baseline 3

1. Unscramble the letters:  
uby

1. boy
2. buy
3. bug

2. Unscramble the letters:  
agt

1. tag
2. cat
3. got

3. Unscramble the letters:  
sdek

1. desk
2. skid
3. deck

4. Unscramble the letters:  
ulpl

1. pool
2. loop
3. pull

5. Unscramble the letters:  
utn

1. nut
2. ton
3. ant

#### Set A

1. Unscramble the letters:  
nki

1. ink
2. sink
3. tin

2. Unscramble the letters:  
tca

1. tack
2. cut
3. act

3. Unscramble the letters:  
dlo

1. doll
2. old
3. lad

4. Unscramble the letters:  
tsa

1. ask
2. sat
3. stay

5. Unscramble the letters:  
rocd

1. rock
2. card
3. cord

6. Unscramble the letters:  
alpm

1. laps
2. plan
3. palm

7. Unscramble the letters:  
nsw o

1. snow
2. wins
3. news

8. Unscramble the letters:  
esls

1. less
2. sell
3. lease

9. Unscramble the letters:  
lil

1. lie
2. ill
3. low

10. Unscramble the letters:  
owrg

1. row
2. wag
3. grow

Set B

1. Unscramble the letters:  
afn

1. nap
2. fan
3. ant

2. Unscramble the letters:  
tpo

1. pet
2. top
3. but

3. Unscramble the letters:  
ofgr

1. fork
2. frog
3. grow

4. Unscramble the letters:  
nrgi

1. girl
2. gain
3. ring

5. Unscramble the letters:  
lowb

1. lamb
2. bowl
3. wool

6. Unscramble the letters:  
ewn

1. won
2. new
3. when

7. Unscramble the letters:  
itle

1. elite
2. tile
3. tilt

8. Unscramble the letters:  
esno

1. noose
2. snow
3. nose

9. Unscramble the letters:  
neop

1. pen
2. open
3. nape

10. Unscramble the letters:  
etre

1. tree
2. rate
3. eater

### Scrambled Words, Level 2

#### Baseline 1

1. Unscramble this word:  
urb
2. Unscramble this word:  
kloc
3. Unscramble this word:  
libo
4. Unscramble this word:  
uct
5. Unscramble this word:  
eci

#### Baseline 2

1. Unscramble this word:  
glod
2. Unscramble this word:  
yrpa
3. Unscramble this word:  
lpac
4. Unscramble this word:  
nrab
5. Unscramble this word:  
odnw

## Baseline 3

1. Unscramble this word:  
ndba
2. Unscramble this word:  
alcl
3. Unscramble this word:  
aaer
4. Unscramble this word:  
lmpu
5. Unscramble this word:  
owgn

## Set A

1. Unscramble this word:  
epn
2. Unscramble this word:  
eht
3. Unscramble this word:  
eyk
4. Unscramble this word:  
ewt
5. Unscramble this word:  
roa
6. Unscramble this word:  
rbdi
7. Unscramble this word:  
ilpl
8. Unscramble this word:  
ocw
9. Unscramble this word:  
losa
10. Unscramble this word:  
veen

## Set B

1. Unscramble this word:  
oyu
2. Unscramble this word:  
ksa
3. Unscramble this word:  
ufn
4. Unscramble this word:  
avn
5. Unscramble this word:  
ogwl
6. Unscramble this word:  
ipr
7. Unscramble this word:  
erba
8. Unscramble this word:  
efre
9. Unscramble this word:  
thu
10. Unscramble this word:  
ajm

## Scrambled Words, Level 3

## Set A

1. Unscramble the letters:  
mslie
  1. missile
  2. lines
  3. slide
  4. smile



2. Unscramble the letters:  
oadir

1. drive
2. dairy
3. radio
4. rodeo

3. Unscramble the letters:  
sesoh

1. south
2. shops
3. shoes
4. shuts

4. Unscramble the letters:  
chuln

1. lunch
2. chain
3. lucky
4. clunk

5. Unscramble the letters:  
nmoht

1. thumb
2. mouth
3. thing
4. month

6. Unscramble the letters:  
npelci

1. pelican
2. plain
3. pencil
4. cancel

7. Unscramble the letters:  
drefni

1. afraid
2. drift
3. refund
4. friend

8. Unscramble the letters:  
inmute

1. tennis
2. minute
3. muted
4. mitten

9. Unscramble the letters:  
tnoess

1. notice
2. nests
3. toasts
4. stones

10. Unscramble the letters:  
ltrtee

1. letter
2. trailer
3. retail
4. rental

Set B

1. Unscramble the letters:  
uheso

1. house
2. horse
3. mouse
4. shoes

2. Unscramble the letters:  
cuhco

1. choke
2. couch
3. shout
4. chuck

3. Unscramble the letters:  
zrora

1. zeroes
2. razor
3. roars
4. sorry

4. Unscramble the letters:  
imcco

1. mirror
2. cocoa
3. mimic
4. comic

5. Unscramble the letters:  
ssmiw

1. warms
2. smile
3. swims
4. smash

6. Unscramble the letters:  
irnegf

1. grief
2. finger
3. ranger
4. anger

7. Unscramble the letters:  
pannik

1. napkin
2. panic
3. picnic
4. candle

8. Unscramble the letters:  
caejtk

1. jacket
2. reject
3. target
4. packet

9. Unscramble the letters:  
nnedir

1. enter
2. redden
3. dinner
4. diner

10. Unscramble the letter:  
      etters

1. letter
2. street
3. trust
4. steer

Scrambled Words, Level 4

Set A

1. Unscramble this word:  
      osnei
2. Unscramble this word:  
      gluha
3. Unscramble this word:  
      yeonm
4. Unscramble this word:  
      thwac
5. Unscramble this word:  
      amwno
6. Unscramble this word:  
      dbrae
7. Unscramble this word:  
      rchia
8. Unscramble this word:  
      nspila
9. Unscramble this word:  
      ewtrin
10. Unscramble this word:  
      efernd

Set B

1. Unscramble this word:  
      glrae
2. Unscramble this word:  
      tasbl

3. Unscramble this word:  
voeim
4. Unscramble this word:  
ntunle
5. Unscramble this word:  
cnache
6. Unscramble this word:  
dtalen
7. Unscramble this word:  
dpraek
8. Unscramble this word:  
rtelea
9. Unscramble this word:  
iarimp
10. Unscramble this word:  
nnesti

## APPENDIX II

### Exit Questions

1. Did you prefer doing the exercises on the computer or in the workbook?
2. Do you think you answered more questions correctly on the computer, in the workbook, or about the same in both?
3. Have you used a computer before?
4. If so, under what circumstances? How often?

## APPENDIX III

### Definition of Terms

The following definitions and test descriptions are excerpted from Nicolosi et al. (1989), Rosenbek et al. (1989), and Sohlberg and Mateer (1989).

**anomia:** Loss of the ability to identify or to recall and recognize names of persons, places, or things.

**aphasia:** Communication disorder caused by brain damage and characterized by complete or partial impairment of language comprehension, formulation, and use; excludes disorders associated with primary sensory deficits, general mental deterioration, or psychiatric disorders.

**Broca's aphasia:** Nonfluent, predominantly expressive aphasia characterized by problems with initiation of sound sequences in words and associated with a lesion in the third frontal convolution of the left or dominant hemisphere; grammar and vocabulary are restricted, so that speech is often limited to expression of high-frequency content words; auditory comprehension is intact, allowing the individual to communicate information through yes-no or multiple-choice questions; writing is often affected.

**carryover:** In speech, the habitual use of newly learned speech or language techniques in everyday situations.

**cognitive treatment:** Therapeutic process of increasing or improving an individual's capacity to process and use incoming information so as to allow increased functioning in everyday life. This includes both methods to restore cognitive function and compensatory techniques, and applies to methods that actually retrain or alleviate problems caused by deficits in attention, visual processing, language, memory, reasoning/problem solving and executive functions.

**Porch Index of Communicative Abilities (PICA):** Aphasia; evaluates communicative ability in adults, in areas of auditory comprehension, reading, oral expressive language, pantomime, visual matching, writing and copying.

pragmatics: Set of rules governing the use of language in context.

The Coloured Progressive Matrices (Raven): Described as a test of observation and clear thinking; consists of 3 sets of 12 problems arranged to assess cognitive processes; requires few verbal instructions; suggested use in conjunction with a vocabulary test; for all ages.

Token Test for Receptive Disturbances in Aphasia (DeRenzi and Vignolo): A test for adults designed to be especially sensitive to the detection of receptive disturbances so slight that they may be overlooked during the course of a clinical evaluation.

transcortical motor aphasia: Aphasia characterized by moderately to mildly impaired auditory comprehension, nonfluent, severely impaired spontaneous speech, but better than expected repetition skills.

Wernicke's aphasia: Fluent, predominantly receptive aphasia characterized by varying degrees of impaired auditory comprehension, with circumlocutory or jargon speech; word-finding problems and paraphasias are common.